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The Cardiorespiratory Responses and Energy Expenditure of Windsurfers during Cycle Ergometer And Windsurfing Simulator Exercise Tests

by

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The aim of the study was a comparative assessment of cardio-respiratory responses and energy expenditures in Polish windsurfers (male) during cycloergometer and windsurfing simulator exercise tests with progressive load till exhaustion. For reproduction of resistance during sail movements on the windsurfing simulator (own design) the rowing ergometer was used, the rope of which was fastened to the middle part of the bom. VO_2, VCO_2 at critical and at heart rate of 170 bpm were measured by a portable metabolimeter COSMED (K4 B-2). Energy expenditures were calculated too. The results show lower peak of power, maximal oxygen uptake and a greater "oxygen deficit" during the windsurfing simulator exercise in comparison to the cycloergometer test. The results confirm a notion about windsurfing as a high-energy expenditure sport, which show high aerobic demands. The results of the study permit to reveal correspondence of the data received during windsurfing simulator and cycle ergometer exercise tests and to make respective corrections in their interpretation for objective estimation of windsurfer's functional performance.

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Introduction

Growing popularity of board sailing (windsurfing), inclusion it into Olympic sports and pumping actions allowed during competition have resulted in need of physiological response analysis. Boardsailing was recently regarded as a sport of moderate physical effort. For that reason, technique of sailing was more important than work capacity. Because of cancellation of the pumping, the ISAF proposed the Medical Commission of IOC to analyze the physiological demands of board sailing during the Olympic class contest "Mistral One Design" (Newton 1995; Bornhoft 2001).

The estimation of windsurfers' cardiorespiratory fitness and energy expenditure of high performance athletes is a necessary condition for effective realization of training and competitive practice (Golinski 1995). Reliability of laboratory results is dependent on approximation of testing exercises under natural conditions of training and competition. Testing surfers on a treadmill or cycloergometer isn't appropriate because these exercises are not similar to windsurfing. Physical loads under pumping may be reproduced by using the windsurfing simulator (Jaszczur-Nowicki and Tomiak 2004). It creates a certain advantage in studies which compare natural conditions of training and competitions.

Material and methods

The study was carried out at the Academy of Physical Education and Sport in Gdansk. Six high level Polish windsurfers (male, Olympic and national team members) and five average windsurfers (22-27 years old) took part in this research. They performed tests on the cycloergometer and windsurfing simulator designed by Jaszczur-Nowicki (fig. 1).

The workload was increased by 25W during cycloergometer and 10W during the windsurfing exercise tests every two minutes till exhaustion. Heart rates (HR) were registered by heart rate monitors (Polar, Finland) during critical power and power at HR of 170 bpm every 2 min.

For the determination of VO_2 and VCO_2 a portable metabolimeter COSMED (K4 B-2) was used. It permitted to calculate energy expenditures (kJ $kg^{-1} \cdot min^{-1}$ and S kJ during the 40 min exercise that corresponded to average time of a single race) at average HR (HR_{av}) of 142 and 168 bpm during regatta conditions of strong (6 – 7 B^0) and weak (1 – 2 B^0) winds respectively (Jaszczur-Nowicki 2002). Statistic analysis included the determination of average values ($\bar{x}$), standard deviations (SD), significance of differences between indexes by t-

Student test and correlation coefficients (r) by use of "STATISTICA 6.0" computer program. For determination of differences between indexes of energy "cost" of windsurfer's work at cycle ergometer and windsurfing simulator exercise tests the Z_a-criterion of symbols was used (? ???????? ? .? . 1974).

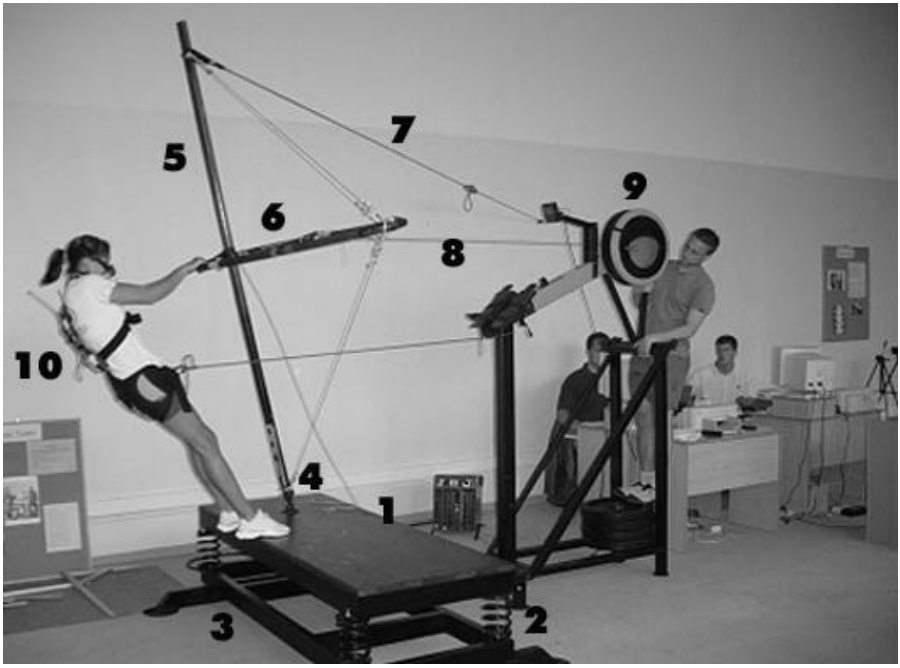

Fig. 1

Design of the simulator

Simulator consists of wooden platform /1/ which is placed on four steel springs /2/ fastening at the metallic frame /3/. On the platform the hinge /4/ is placed to the lower part of mast /5/ with a fastened boom /6/ which size is corresponding to "Mistral One Design". From mast top come off the gum expander /7/ which provides sail return during pumping. In the middle part of the boom a tensometric element is connected to the computer complex /8/ registering power. For the reproduction of resistance during sail movements we used the rowing ergometer /9/ the rope of which was fastened at middle part of the boom from leeward side. Parallel it is possible to carry out a physiology monitoring (using a portable metabolimeter "COSMED" for example /10/).

Results

The data, presented in table 1, give evidence about significant correlation between the studied indexes under work power at HR 170 bpm during cycle ergometer and windsurfing simulator exercise tests. However the indexes of absolute power (W_{170}) and relative power ($W_{170} \cdot kg^{-1}$) during windsurfing simulator exercise test were significantly (~at 2.5 time) lower in comparison to those observed during cycle ergometer test ($p=0.05$).

Table 1

*Cardiorespiratory reactions of elite windsurfers at cycle ergometer and windsurfing simulator exercise tests (n = 6; * p=0.05; ** p=0.01; *** p=0.001)*

Conditions of indexes determination	**Ergometer**	**Statistics**	**Indexes**				
			HR bpm	VO_2 $l \cdot min^{-1}$	VO_2 $ml \cdot min^{1} \cdot kg^{-1}$	W	$W \cdot kg^{1}$
Work at HR: 170 bpm	Cycle ergometer	M		3037	44,8	250	3,7
		SD		760	6,8	57	0,5
	Windsurfing simulator	M		2595	38,5	97 *	1,4 *
		SD		514	4,2	24	0,2
		r		0.99 *	0.95 *	0.84 *	0.80 *
Work till exhaustion	Cycle ergometer	M	191,2	3843	57,2	358	5,3
		SD	8.0	555	3.2	56	0.3
	Windsurfing simulator	M	184.5	3053	45.5**	138 **	2.1 ***
		SD	6.3	395	2.0	20	0.1
		r	0.90*	0.98 *	0.82 *	0.68	- 0.32

Similar situation was noted under critical work power which during cycle ergometer and windsurfing simulator exercise tests was equal to 5.3±0.3 $W \cdot kg^{-1}$ and 2.10±0.1 $W \cdot kg^{-1}$ respectively. In this case relationship between relative critical power indexes was low. Presented in table 1 data of windsurfing simulator and cycloergometer tests indicate values of VO_2 equal to 38,5±4,2 $ml \cdot min^{-1} \cdot kg^{-1}$ and 44,8±6,8 $ml \cdot min^{-1} \cdot kg^{-1}$ respectively. The differences between these indexes were not statistically significant.

During work till exhaustion in the simulator test the average HR corresponds to 184.5±6.3 bpm and VO_2 to 45.5±2.0 $ml \cdot min^{-1} \cdot kg^{-1}$ whereas during the cycloergometer exercise these indexes are equal to 191.2±8.0 bpm and 57.2±3.2 $ml \cdot min^{-1} \cdot kg^{-1}$. In this case the difference between VO_2 indexes in both tests is statistically significant ($p=0.001$).

Table 2

Energy "cost" of windsurfer's work at cycle ergometer and windsurfing simulator exercise tests at HR_{av} corresponding of physical loads during regattas at strong (6 –7 B^0, HR_{av}: 142 bpm) and weak (1 – 2 B^0, HR_{av}: 168 bpm) wind conditions (n = 11)

Ergometer	Statistics	kJ·kg^{-1}·min^{-1}		S kJ during 40 min exercise	
		HR_{av} 142 bpm	HR_{av} 168 bpm	HR_{av} 142 bpm	HR_{av} 168 bpm
Cycle ergometer	Means	42.3	62.8	1693	2403
	SD	9.6	10.4	336	452
Windsurfing simulator	Means	38.1	51.5	1516	2043
	SD	9.4	9.5 *	414	431 *

* difference is significant as regards to cycle ergometer test at HR_{av} 168 bpm under a < 0,01

The results of this study confirm the substantial energy "cost" cycloergometer and windsurfing simulator exercise tests (tab. 2). Most significant energy expenditures in elite windsurfers at HR 168 bpm (regatta conditions of weak wind) during the 40 min. exercise are achieved at 2500 kJ. During cycloergometer test this index is higher.

Discussion

Comparative analysis of our laboratory results with data obtained during regatta by Vogiatzis et al. (2002) is similar with research indexes. The VO_2 of high performance windsurfers during intense pumping equals to 48.4±5.7 ml·min^{-1}·kg^{-1} what coincide with presented data: 44.8±6.8 ml·min^{-1}·kg^{-1}. It indicates that the windsurfing simulator may be applied for control of the windsurfers' performance under laboratory conditions. In comparison with cycle ergometer test the respiratory indexes during the windsurfing simulator reach smaller values. That fact may be explained by more muscle groups participating during cycloergometer test.

The results confirm a notion about windsurfing as a high-energy expenditure sport which shows high demands of the aerobic metabolism of the athletes, especially under weak wind conditions (deVito et al. 1997). Such exercise may be related to submaximal aerobic power under which the oxygen energy delivers close to 95% (Koc 1987). It should be indicated that during one regatta day the windsurfers take part in four races thus the aerobic capacity my

significantly reflect the windsurfers performance. The results this research indicate more significant energy expenditure of elite windsurfers at HR_{av} 168 bpm during the windsurfing simulator test (2500 kJ during 40 min. of exercise). During cycloergometer test this index is always higher.

Conclusions

3. Close correlation between VO_2 and work power indexes at HR 170 bpm during cycle ergometer and windsurfing simulator exercise tests was established. The indexes of power (but not VO_2) during windsurfing simulator exercise test were significantly lower as compared to those observed during cycle ergometer exercise test.
4. During critical work power close correlation between work power indexes during cycle ergometer and windsurfing simulator exercise tests was absent, whereas correlation between VO_2 indexes was high. The VO_2 index during the cycloergometer test was lower than observed during the simulator test.
5. The results confirm a notion about windsurfing as a high-energy expenditure sport, which show high demands of aerobic metabolism of athletes especially under weak wind conditions.
6. The results of the study permit to reveal a correspondence of the data received during windsurfing simulator and cycle ergometer exercise and to make a respective correction in their interpretation for objective estimation of windsurfers' functional performance.

References

Bornhoft S (2001). Windsurfing. Stakpole Books.

Golinski M (1995). Glówne kierunki rozwoju windsurfingu. Niektóre Wspólczesne Uwarunkowania Rozwoju Zeglarstwa. AWF w Gdansku, 35 – 48.

De Vito G, DiFilippo L, Rodio A, Felici F, Madaffari A (1997). Is the Olympic board sailor an endurance athlete? Int J Sports Med, 18 (4): 281-284.

Jaszczur-Nowicki J. (2002). Reakcja ukladu krazenia zeglarza deskowego w zaleznosci od sily wiatru podczas wyscigu regatowego. Rocznik NaukowyAWFiS, Gdansku, IX: 289 – 293.

Jaszczur-Nowicki J, Tomiak T (2004). Ocena mozliwosci modelowania funkcjonalnych wymagan typowych dla zeglarzy deskowych w warunkach laboratoryjnych. In: A. Kuder, K. Perkowski, D. Sledziewski (Eds.) Kierunki doskonalenia treningu i walki sportowej – diagnostyka, (pp. 92–95). Warszawa.

? ???????? ? ? (1974). ??????????-?????????????? ?????? ? ??????. ? ?????, ??????????? ? ?????: 49 – 50.

Newton F (1995). Factors affecting boardsailing performance. International Yacht Racing Union (unpublished medical report).

Vogiatzis I, DeVito G, Rodio A, Madaffari A, Marchetti M (2002). The physiological demands of sail pumping in Olympic level windsurfing. Eur J Appl Physiol, 86: 450-454.